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II

THE POST-EOCENE FORMATIONS OF WESTERN WASHINGTON

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INTRODUCTION

Marine deposits of post-Tejon age form a considerable part of the formations exposed at the surface in western Washington. They have been folded and eroded, and, in some areas, are deeply buried beneath sand and gravel of glacial and fluviatile origin. As a result, outcrops are usually found in the form of low cliffs along the banks of rivers and creeks or along the sea cliffs of the Sound or ocean. Certain portions of these Oligocene-Miocene formations yield fairly abundant marine invertebrate faunas. Upon a faunal basis five separate divisions of the post-Tejon portion of the Tertiary can be recognized. Marine deposits of Pliocene age with the exception of a very small area on the western side of the Olympic Peninsula are unknown within the state. The uppermost division or upper Miocene is separated from the lower four divisions by a well-marked unconformity. The pre-Pleistocene formations of the southwestern portion of the state are somewhat ob-

scured by clays, sands and gravels of fluviatile origin. In many areas the Tertiary rocks themselves have been so deeply weathered that very little information can be obtained concerning their lithologic character and structure. All parts of western Washington are clothed with a dense growth of forest and underbrush, which conceals many exposures of Tertiary rocks which are not covered with Pleistocene sands and gravels.

LITERATURE

Numerous references to the occurrence of Tertiary strata may be found in papers dealing with the geology of western Washington. The majority of these papers involve investigations of economic products such as coal and contribute little to the purely scientific phases of Tertiary geology. Only the more important literature is here reviewed.

James D. Dana referred to Tertiary strata in the report on the geology of the United States Exploring Expedition under Wilkes[1] as occurring to the north of Columbia River and along the shores of Puget Sound and the Strait of Juan de Fuca. Collections were made from the south side of Columbia River at the town of Astoria. This fauna was identified by Conrad, who regarded it as Miocene.

Marine Neocene deposits are mentioned by Dr. Bailey Willis as occurring near Seattle immediately north of the northern limits of the Tacoma quadrangle.[2] These deposits are not described.

The first detailed description of the occurrence of Oligocene-Miocene strata within the state is to be found in a report by Dr. Ralph Arnold[3] on a "Geological Reconnaissance of the Coast of the Olympic Peninsula, Washington." Oligocene-Miocene deposits are described as occurring along the northern border of the Olympic Peninsula. Pliocene deposits are mentioned as being present on the west coast of the peninsula near the mouth of Queniult River. The Miocene deposits are composed of conglomerates, sandstones and shales which at-

[1]Dana, J. D., in U. S. Exploring Expedition, under command of Charles Wilkes, U. S. N., Philadelphia, vol. 10, 1838-1842.
[2]Willis, Bailey, Tacoma Folio, No. 54, U. S. Geological Survey, 1896.
[3]Arnold, Ralph, Bulletin Geological Society of America, vol. 17, pp. 451-468, September, 1906.

tain a thickness of 15,000 feet and have been folded into anticlines and synclines. Upon the basis of faunal evidence he states that the fossils of the formation indicate that the basal portion of the series is Oligocene in age, while the upper part is certainly Miocene. Since the separation of the two members will necessarily have to be made on paleontological grounds and will require a more detailed study of the material in hand than time has yet permitted, the term "Oligocene-Miocene series" will be used temporarily to designate the age of the beds. Arnold applied the term to this formation and recognized five faunal zones within it.

Further mention is made concerning the occurrence of Oligocene and Miocene fossils at Restoration and Beans points, just west of Seattle, by Dr. Ralph Arnold[4] and Dr. W. H. Dall.[5]

A paper published in 1908 by A. B. Reagan[6] and entitled "Some Notes on the Olympic Peninsula," describes the Tertiary rocks occurring in certain localities along the north and west sides of the Olympic Peninsula. Several new species of mollusks are described and figured.

In 1911, the writer, in a preliminary paper on the Tertiary of western Washington, described in a general way the distribution of the Miocene formations within the state. The following subdivisions were made: Lincoln formation of Oligocene age; Blakeley, Wahkiakum and Chehalis formations of Lower Miocene age, and the Montesano of Upper Miocene. Since the appearance of that paper, more detailed field work has been done by the writer. As a result, a large portion of the Chehalis formation is now included within the Wahkiakum and Montesano formations, and another division intermediate between the Lincoln and Blakeley is introduced, namely, the Porter.[7] The area along the western border of the Olympics represented upon the map accompanying the report as undifferentiated Lower Miocene, is of probable Jurassic age and is now referred to as the Hoh formation.

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[4]Arnold, Ralph, Professional Paper No. 47, U. S. G. S., "The Tertiary and Quaternary Pectens of California," Washington, 1905.

[5]Dall, W. H., Professional Paper No. 59, U. S. G. S., "The Miocene of Astoria and Coos Bay, Oregon," Washington, 1906.

[6]Reagan, A. B., "Some Notes on the Olympic Peninsula," Kansas Acad. Sci. Geological Papers, pp. 131-238, 1908.

[7]Weaver, C. E., "A Preliminary Report on the Tertiary Palaeontology of Western Washington," Bulletin No. 13, Washington Geological Survey, 1911.

The most recent paper on the Tertiary of western Washington is by Arnold and Hannibal[8] on the Marine Stratigraphy of the North Pacific Coast of America, published in 1913. A four-fold division of the Oligocene is recognized. The oldest is represented by the Sooke formation of southwestern Vancouver Island. This is followed by the San Lorenzo, Seattle and Twin River formations. Above this is the Monterey, which is thought to be in part Oligocene and possibly in part lower Miocene. The upper Miocene strata, which are described as occurring on the south and west portions of the Olympic Peninsula, are believed to be the equivalent of the Empire formation of Coos Bay, Oregon.

GEOGRAPHIC DISTRIBUTION

The Oligocene and Miocene deposits of western Washington exist in three separate areas. The largest and most representative area occupies the northern half of the Puget Sound basin and the north border of the Olympic Peninsula. A second area embraces the western portion of the Chehalis and Willapa river valleys in the southwestern part of the state. A third area constitutes a belt ranging from five to fifteen miles in width and trending east and west along the north shore of Columbia River. Within the Puget Sound basin and along the northern portion of the Olympic Peninsula, Miocene sediments are for the most part more or less heavily covered with deposits of glacial drift. They appear in the form of low sea cliffs along the shores of the entrance to the Bremerton Navy Yard, in the streets in the southern portions of the city of Seattle, and along the northern slopes of the Newcastle Hills. Along the north border of the Olympic Peninsula rock exposures appear almost continuously from Cape Flattery eastward to Port Crescent. Similar deposits occur within and along the shores of portions of the Quimper Peninsula south of Port Townsend. The Puget Sound Basin Oligocene and Miocene area is separated from that of southwestern Washington by basalts and sedimentary rocks of Eocene age. From the southern margin of the Olympic Moun-

[8]Arnold, Ralph, and Hannibal, Harold, "Marine Stratigraphy of the North Pacific Coast of America," Proc. Amer. Philos. Soc., vol. 53, No. 212, November-December, 1913.

tains in Chehalis County, Oligocene and Miocene formations extend southerly to the middle of Pacific County. Outlying residuals occur in western Thurston and Lewis counties. Similar deposits of post-Tejon age are present in Wahkiakum County and in the southwestern part of Pacific County. They have been cut by the Columbia River and their southern extension forms a part of the well-known series of outcrops occurring at Astoria, Oregon. No marine deposits of Oligocene or Miocene age are known to occur within the Cascade Mountains or within the great basin area of eastern Washington. In these regions deposits of corresponding age are of igneous or freshwater origin.

SEDIMENTATION

From the standpoint of stratigraphy the post-Tejon sediments occurring in the western part of the state are divided into two broad groups, separated by a well-marked unconformity. The older division includes deposits of Oligocene and lower Miocene age, while the younger involves sediments of upper Miocene and possibly lower Pliocene ages. During the Oligocene, embayments of the ocean were widely extended over western Washington with the exception of the central and western portions of the Olympic Peninsula. During the lower Miocene their extent became much smaller and by the opening of the upper Miocene they were almost entirely withdrawn. During the upper Miocene two small, shallow basins of deposition were formed. One of these existed in the basin of Grays Harbor and the other near the junction of Bogachiel and Solduc rivers in southwestern Clallam County.

During the Eocene epoch, southwestern Washington was occupied by an embayment of the ocean which seems to have extended as far north as the middle portion of the present Puget Sound basin. This fact is indicated by the occurrence of narrow bands of marine strata interbedded with those of purely brackish water origin. On the eastern shores of this embayment were situated extensive estuaries in which over 10,000 feet of brackish water sediments were deposited and which now form extensive outcrops in King, Pierce and Lewis counties. Igneous activity was characteristic of the larger

portion of the Tejon epoch but had almost entirely ceased by the opening of the Oligocene epoch. Near the close of the Eocene or at the opening of the Oligocene minor crustal movements brought about an encroachment of the marine waters into the Puget Sound basin and also into the present site of the Strait of Juan de Fuca.

In southwestern Washington the oldest deposits of post-Eocene age occur west of the city of Centralia in the valley of Chehalis River. They consist of indistinctly bedded, sandy, gray shales containing a marine invertebrate fauna which will be referred to in this report as the Molopophorus lincolnensis zone. The strata containing the fauna may be referred to as the Lincoln horizon. At the present time the strata at this locality are approximately 1,000 feet in thickness. Away from stream, railway or wagon road cuts, rock exposures are largely obscured by a veneer of sands, clays and gravels, rendering it difficult to determine the exact areal limits of these beds. Fossiliferous strata outcropping in the banks of Olequah Creek near the town of Winlock and in the banks of Cowlitz River, six miles east of Vader, at the Graeco Ranch, may have been contemporaneously deposited with those at Lincoln Creek. The same may be true of the shales on Porter Creek north of the town of Porter in Chehalis County. They are unknown to the southwest in Pacific and Wahkiakum counties, as well as along the Strait of Juan de Fuca.

Toward the close of deposition of the Lincoln sediments the Oligocene seas expanded and occupied portions of the Strait of Juan de Fuca and the Puget Sound basin, as well as most of southwestern Washington. By the close of the Oligocene epoch these deposits had attained a maximum aggregate thickness of 15,000 feet. They consist predominately of shales and sandy shales within which local beds of conglomerate and sandstone are occasionally interbedded. The thickest and most complete section of the Oligocene is to be found in northern Clallam County along the northern border of the Olympic Peninsula. The section measured between Cape Flattery and Clallam Bay possesses a thickness of 13,300 feet. The basal beds are situated at the west end of Wyatch Slough and the upper about half way between Neah Bay and Clallam Bay.

Cape Flattery Section

Top

	Feet
Massive sandstone	700
Chiefly shale, mostly concealed	900
Massive sandstone	175
Chiefly shale, mostly covered	800
Massive brown sandstone	300
Concealed	500
Massive, medium grained, brown sandstone	300
Alternating bands of grayish brown shale and sandstone	1,200
Brown sandstone	200
Conglomerate	30
Brown sandstone	50
Conglomerate	50
Conglomerate with interbedded layers of shale	500
Coarse conglomerate	300
Grayish brown shale	700
Interbedded sandstone, shale and conglomerate	200
Massive, pebbly conglomerate	175
Hard, flinty shale	200
Sandstone with some interbedded shale	400
Interbedded massive sandstone and conglomerate	450
Massive conglomerate	30
Massive sandstone and intercallated conglomerate lense	300
Sandy conglomerate as exposed at Cape Flattery	1,400
Interbedded sandstone and shale	150
Concealed, probably shale	500
Laminated sandy shale	200
Interbedded conglomerate and sandstone	250
Shale	350
Gritty sandstone with some interbedded shale	250
Brown shale	1,200
Brown banded sandstone	300
Total	13,300

Structurally the strata just described are involved in the badly wrinkled southwestern limb of a syncline whose axis trends from Port Crescent northwesterly diagonally across the Strait of Juan de Fuca. The strata forming the northeasterly limb occur fringing the south coast of Vancouver Island.

Deposits of Oligocene age are well developed in the low cliffs along the entrance to the Bremerton Navy Yard. These beds are a continuation of those occurring to the east at Alki Point and South Seattle, as well as along the north flanks of the Newcastle Hills. They have been sharply folded and deeply dissected by erosion, and later covered with deposits of glacial drift. The following generalized stratigraphic section has been constructed. The lowest beds exposed in the section outcrop at Orchard Point on the south side of Brem-

erton Inlet and the highest beds along the north shore of the entrance to Blakeley Harbor.

TOP OF SECTION

	Feet
Massive, coarse grained conglomeratic sandstones containing numerous lenticular bands of conglomerates. Occasional, narrow bands of clay shale are interbedded	1,300
Sandy shales exposed beneath the waters of Blakeley Harbor	1,400
Brownish gray, massive to slightly bedded, sandy shales as exposed along the south shore of Blakeley Harbor for a distance of one-half mile northwesterly	2,400
Shaly sandstone grading in places into a shale. Stratification well defined. Upper portion of this belt is located at Restoration Point	1,200
Shaly sandstones gradually becoming more sandy in depth. Bedding, very distinct	450
Massive, sandy shales	350
Massive, brownish-gray, coarse grained conglomeratic sandstones and interbedded bands of coarse conglomerate, the pebbles of which attain a diameter of two feet. Many of the pebbles are composed of basalt and others of light colored shale and sandstone	1,800
Total	8,900

SEQUENCE OF FAUNAS

In the report by Arnold and Hannibal on the "Stratigraphy of the North Pacific Coast," deposits of Oligocene age are referred to as the Astoria Series. This series is divided into three divisions, namely: the San Lorenzo, Seattle and Twin River formations. The distinctions between these formations are largely based upon differences of faunas rather than upon lithologic grounds. In the opinion of the writer, it would be preferable to refer to these divisions as faunal zones rather than formations. The application of the term San Lorenzo formation to the deposits described as such in Washington seems hardly justifiable. The type locality for the San Lorenzo is located in the Coast Ranges of California. Whether the strata assigned to the San Lorenzo in western Washington represent a part, all, or more than that, belonging to the formation in California, has not been determined. Until such information is available it would be misleading to make such direct correlation. If future investigations should prove that the deposits were formed contemporaneously, the term could with justice be introduced. Studies made by the writer on

faunas collected from the type localities of the Twin River and Seattle formations do not indicate sufficient grounds for making a separation. The Seattle formation is described as occurring on the south shore of the Strait of Juan de Fuca east of Twin River and east of Gettysburg. Detailed mapping in this region shows conclusively that the strata occurring there are involved in the east and west limbs of a syncline, and stratigraphical measurements prove the strata in question on each limb of this syncline to be identical. The arguments which have just been made concerning the use of the term San Lorenzo in Washington, at present at least, may be applied to the introduction of the term Monterey and Empire. The exact use of the term Monterey has not been definitely agreed upon in California. As more and more detailed information is obtained there is divergence of opinion as to what is to be included within the meaning of the term Monterey. The faunas of Washington and Oregon are not at present sufficiently known to permit any direct correlations. Suggestions can be made, but it would seem preferable to the writer to use local names provisionally and to gather all the information possible concerning formations or faunal zones in Washington and later, when such information is at hand, both in California and Washington, to make direct correlations. Misunderstandings as to what the writers are intending to convey will be less common. The gathering and recording of accurate information in the field is much more desirable than the attempt to make broad correlations with distant areas on insufficient and imperfect field data. After detailed studies have been made, such correlations can be made with confidence. In the meantime suggested similarities can be placed on record.

Five distinct faunal zones can be recognized in the post-Tejon strata of western Washington. The following table will illustrate their sequence:

Montesano horizon—Yoldia strigata zone. . . . Upper Miocene
—unconformity—

Wahkiakum horizon—Arca montereyana zone. Lower Miocene
—unconformity—

Blakeley horizon—Acila gettysburgensis zone.....Oligocene
Porter horizon—Turritella porterensis zone.....Oligocene
Lincoln horizon—Molopophorus lincolnensis zone..Oligocene
Tejon group .....Eocene

MOLOPOPHORUS LINCOLNENSIS ZONE

The oldest post-Tejon fauna which has been recognized within western Washington occurs in sandy shales outcropping along the south bank of Chehalis River five to 10 miles west of the city of Centralia, in Thurston County. Fossils in this locality are fairly abundant and in an excellent state of preservation. An examination of the faunal lists from this region indicates that several of the species are identical with those occurring in the underlying Tejon Eocene. Among these are *Brachysphingus clarki* Weaver, *Leda uvasana* Dickerson, *Crassatellites washingtoniana* Weaver, *Exilia dickersoni* Weaver, *Hemifusus washingtonianus* Weaver, and *Strepsidura oregonensis* Dall.

The following species have been recognized as occurring in the rock bluffs along the south bank of Chehalis River west of Lincoln Creek. The strata containing the fauna may be referred to as the Lincoln horizon[9] and the fauna itself as the Molopophorus lincolnensis zone.

Pelecypoda

Cardium lincolnensis Weaver
Cardium lorenzanum (Arnold)
Crassatellites washingtoniana Weaver
Crassatellites cowlitzensis Weaver
Crenella porterensis Weaver
Leda uvasana Dickerson
Leda lincolnensis Weaver
Macrocallista pittsburgensis Dall
Nucula washingtonensis Weaver
Ostraea lincolnensis Weaver
Solen curtus Conrad
Solen parallelus Gabb
Pitaria dalli Weaver

Scaphapoda

Dentalium stramineum Gabb

Brachiopoda

Terebratalia, sp.

[9]The use of the term Horizon is in the sense of a deposit formed at a particular time and identified by distinctive fossils.

GASTEROPODA

Ampullina, new species
Brachysphingus clarki Weaver
Bittium lincolnensis Weaver
Cancellaria, new species
Calyptræa washingtonensis Weaver
Drillia stanfordensis (Arnold)
Exilia dickersoni Weaver
Hemifusus washingtoniana Weaver
Drillia hecoxi (Arnold)
Lunatia cowlitzensis Dickerson
Scaphander oregonensis Dall
Surcula lincolnensis Weaver
Strepsidura oregonensis Dall
Strepsidura lincolnensis Weaver
Molopophorus lincolnensis Weaver
Turritella newcombi Merriam

The above listed fauna seems to have a closer affinity with that occurring at Porter Bluffs, about 20 miles to the west in Chehalis County, and designated in this report as the Turritella porterensis zone, than to the underlying Eocene. The most important species which occur in common are *Cardium lorenzanum* Arnold, *Crenella porterensis* Weaver, *Dentalium conradi* Dall, *Drillia hecoxi* (Arnold), *Lunatia cowlitzensis* Dickerson, and *Malletia chehalisensis* Arnold.

Marcia oregonensis Conrad, *Thyasira bisecta* (Conrad), *Thracia trapezoidea* Conrad, and *Phacoides acutilineatus* (Conrad) are entirely absent from the Molopophorus lincolnensis zone. They are, however, among the most common species to be found in the Turritella porterensis and Acila gettysburgensis zones.

The following species are most characteristic of the Molopophorus lincolnensis zone: *Cardium lorenzanum* Arnold, *Crassatellites washingtoniana* Weaver, *Leda uwasana* Dickerson, *Macrocallista pittsburgensis* Dall, *Pitaria dalli* Weaver, *Brachysphingus clarki* Weaver, *Exilia dickersoni* Weaver, *Lunatia cowlitzensis* Dickerson, *Drillia hecoxi* (Arnold) and *Strepsidura oregonensis* Dall.

A study of the faunas above listed indicates clearly a marked distinction between the Tejon fauna proper and the Molopophorus lincolnensis zone. A closer relation exists between the latter and the Turritella porterensis zone, although there are sufficient distinctions to warrant considering them separate faunal zones.

TURRITELLA PORTERENSIS ZONE

The type locality at which this fauna may be found is located in the cliffs along the north bank of Chehalis River near the mouth of Porter Creek, in Chehalis County. Exposures of the same strata also occur in the banks of the small creeks entering Chehalis River from the north in the vicinity of Porter Creek. The most common species appearing in this zone are *Cardium lorenzanum* Arnold, *Crenella porterensis* Weaver, *Malletia chehalisensis* Arnold, *Marcia oregonensis* (Conrad), *Thracia trapezoidea* Conrad, *Thyasira bisecta* (Conrad), *Phacoides acutilineatus* (Conrad), *Drillia hecoxi* (Arnold) and *Turritella porterensis* Weaver. Such species as *Acila gettysburgensis* Reagan, *Macrocallista vespertina* (Conrad), *Modiolus directus* Dall, *Panope generosa* (Gould), *Eudolium petrosum* (Conrad), *Turcicula washingtoniana* Dall and *Turritella blakeleyensis* Weaver are absent. These species are, however, among the most characteristic occurring in the Acila gettysburgensis zone. It is possible that the Turritella porterensis zone may be represented beneath the lowermost beds of the Acila gettysburgensis zone south of Orchard Point at the Bremerton Inlet section. If so, it occurs between the lowest conglomerate belt of the Acila gettysburgensis zone and the underlying Eocene basalts near Port Orchard. This region is covered with glacial drift. The lower beds in the Clallam County area as exposed three miles west of Port Crescent may also represent this horizon.

ACILA GETTYSBURGENSIS ZONE

The type locality where this fauna may be found is in the sea cliffs about the entrance to the Bremerton Navy Yard. The lowermost strata occur at Orchard Point. The highest strata outcrop along the north shore of the entrance to Blakeley Harbor. The total thickness of the beds here exposed is 8,900 feet. Detailed stratigraphic surveys show that the conglomerates at Orchard Point are below the sandstones and shales at Bean Point. The beds at Bean Point are about 2,000 feet below the fossiliferous beds at Restoration Point. The fauna

in the lower portion of this section is almost identical with that at the well-known locality just north of Restoration Point. In other words, there appears to be but one faunal zone represented within the strata exposed between Orchard Point at the base of the section and the north shore of Blakeley Harbor at the top of the section.

The most characteristic species of the Acila gettysburgensis zone are *Acila gettysburgensis* Reagan, *Macrocallista vespertina* (Conrad), *Marcia oregonensis* (Conrad), *Modiolus rectus* Dall, *Panope generosa* (Gould), *Phacoides acutilineatus* (Conrad), *Spisula albaria* (Conrad), *Solemya ventricosta* Conrad, *Tellina oregonensis* Conrad, *Thracia trapezoidea* Conrad, *Thyasira bisecta* (Conrad), *Crepidula praerupta* Conrad, *Eudolium petrosum* (Conrad), *Miopleiona indurata* (Conrad), *Turcicula washingtoniana* Dall and *Turritella blakeleyensis* Weaver. Such species as *Acila gettysburgensis* Reagan, *Solemya ventricosta* Conrad, *Eudolium petrosum* (Conrad) and *Turcicula washingtoniana* Dall appear for the first time in this zone. They are always among the most common species met with and are entirely absent from the Turritella porterensis and Molopophorus lincolnensis zones.

ARCA MONTEREYANA ZONE

The recognition of a fauna characteristic of the Arca montereyana zone was first mentioned as occurring in Wahkiakum County on the Alockaman River about 12 miles north of the town of Cathlamet. The strata are composed of sandstones and shales involved in a shallow synclinal trough. Deposits of sandstones and sandy shales outcropping along the Strait of Juan de Fuca from Pysht westerly to Clallam Bay, also contain a fauna belonging to this faunal zone. Similar faunas representing both deep and shallow water phases occur in the shales and sandstones in the Grays Harbor region. The sediments in which they occur were in part formerly referred to by the writer as the Chehalis formation.[10]

A complete list of the species occurring within this zone may be referred to in the faunal table on page 35. Among

[10]Bulletin No. 13, Washington Geological Survey, 1911.

the more characteristic species occurring in this zone are *Arca montereyana* Osmont, *Chione securis* (Shumard), *Diplodonta parilis* Conrad, *Acila conradi* Meek, *Arca trilineata* Conrad, *Marcia oregonensis* (Conrad), *Pecten propatulus* Conrad, *Panope generosa* (Gould), *Phacoides acutilineatus* (Conrad), *Spisula albaria* (Conrad), *Crepidula praerupta* Conrad, *Fusinus stanfordensis* (Arnold), *Polynices saxea* Conrad, *Sinum scopulosum* (Conrad), *Dentalium conradi* Dall, *Aturia angustata* Conrad, *Pecten fucanus* Arnold, *Tellina arctata* Conrad, *Venericardia quadrata* Dall, *Venus olympidea* (Reagan), *Venus clallamensis* (Reagan), *Ficus clallamensis* Weaver, *Tellina nevadensis* Anderson, *Cancellaria dalliana* Anderson, *Cancellaria condoni* Anderson, and *Leda ochsneri* Anderson. This fauna presents a very strong similarity to that occurring in the Monterey formation in California.

YOLDIA STRIGATA ZONE

The upper Miocene strata of western Washington everywhere rest with unconformity upon the older rocks. The fauna occurring within these strata is very different from that of the faunal zones just described. One of the most common and readily recognizable species among this fauna is *Yoldia strigata* Dall. It might be desirable to refer to this fauna as the Yoldia strigata zone.

Among the more characteristic species belonging to this zone are *Arca trilineata* Conrad, *Cardium meekianum* Gabb, *Macoma astori* Dall, *Mulinia densata* Conrad, *Pecten coosensis* Shumard, *Solen sicarius* Gould, *Siliqua nuttallii* Conrad, *Yoldia strigata* Dall, *Argobuccinium cammani* Dall, *Chrysodomus imperalis* Dall, *Phalium aequisulcatum* Dall, *Sinum scopulosum* (Conrad) and *Scutella gabbii* Rémond. A complete list of the species occurring in this zone may be found in the faunal table.

Strata containing fauna of the Yoldia strigata zone outcrop in the Chehalis valley in the vicinity of Grays Harbor, at the mouth of the Queniult River and in the lower valley of the Quillayute River. The faunas of the Quillayute and Queniult valleys may represent a slightly higher position than

those of the Chehalis Basin. Detailed studies at each of those localities will be required to determine that point.

No marine deposits are known to occur within the state younger than those near the mouth of the Queniult Basin except late Pleistocene beach sands around the shores of Puget Sound.

CORRELATION

Sufficient evidence is not as yet at hand to warrant a direct correlation of the faunas or faunal zones of western Washington with those of California. The great unconformity existing between the upper and lower Miocene is general throughout the Pacific coastal region. The faunas of both the upper and lower Miocene are distinctly different in California and Washington. The upper Miocene fauna of Washington appears to have its closest resemblance to the San Pablo of California, but more detailed evidence must be secured before such a definite correlation can be made. The Arca montereyana zone of Washington appears to be the equivalent of the same zone in California. It is possible, however, that more or less may be included within the faunal zone in the north than in the south. The Molopophorus lincolnensis and the Turritella porterensis zones of Washington may be the equivalent of the Agasoma gravidum zone of California. It is possible that the Acila gettysburgensis zone is in part higher than the Agasoma gravidum zone in the south.

CONCLUSIONS

The post-Tejon formations of western Washington consist of shales and sandstones of marine origin. These deposits contain a well-developed fauna which at the present time is imperfectly known. The total maximum aggregate thickness of the sediments is approximately 20,000 feet.

Five well-marked faunal zones are present, the uppermost of which is separated from the lower four by a well-marked unconformity and difference in character of species. This line

of separation is the division line between the upper and lower Miocene. The uppermost of the remaining four faunal zones is separated from the other three by well-marked faunal differences. It is lower Miocene in age while the three lower zones are Oligocene. The faunas of the Oligocene in western Washington show a gradual gradation from one zone into another.

Insufficient evidence is as yet available to warrant making direct correlations with the post-Tejon zones of California, yet suggested similarities appear.

POST-TEJON FAUNAL TABLE FOR WESTERN WASHINGTON

The following table contains a list of the species occurring in the post-Tejon strata of western Washington. A large number of new and undescribed species are present, which are not included within this list.

POST-TEJON FAUNAL TABLE FOR WESTERN WASHINGTON

	Molopophorus lincolnensis Zone	Turritella porterensis Zone	Acila gettysburgensis Zone	Arca montereyana Zone	Yoldia strigata Zone	Recent	Tejon formation of Washington	Astoria	Tunnel Point Beds	Empire	Agasoma gravidum Zone	Arca montereyana, California	San Pablo	Santa Margarita	Etchegoin
PELECYPODA															
Acila conradi Meek				×	×					×			×		
Acila gettysburgensis Reagan			×												
Anomia subcostata Conrad	×														
Arca trilineata Conrad															
Arca montereyana Osmont				×	×							×	×	×	×
Cardium lorenzanum Arnold	×	×	×								×	×			
Cardium lincolnensis Weaver	×														
Cardium coosense Dall					×					×					
Cardium vaquerosensis Arnold				×											
Cardium meekianum Gabb					×					×			×	×	
Chione securis (Shumard)					×					×			×	×	
Chione bisculpta Dall					×					×					
Chione chehalisensis Weaver					×										
Chione montesanoensis Weaver															
Chione clallamensis Reagan				×											
Chione olympidea Reagan				×											
Chione vespertina Conrad			×												
Chione cathcartensis Weaver			×												
Crenella porterensis Weaver	×	×	×					×							
Crassatellites washingtoniana Weaver	×														
Crassatellites cowlitzensis Weaver	×														
Cryptomya oregonensis Dall					×					×					
Cryptomya washingtoniana Weaver					×										
Diplodonta parilis Conrad				×	×	×		×		×			×	×	×
Glycimeris gabbi Dall					×					×					
Leda uvasana Dickerson	×						×								
Leda lincolnensis Weaver	×														
Leda chehalisensis Weaver				×											
Leda penita Conrad				×				×							
Leda ochsneri Anderson				×											
Macrocallista pittsburgensis Dall	×														
Marcia oregonensis Conrad		×	×	×	×			×		×			×	×	
Macoma secta Conrad					×	×							×	×	×
Macoma nasuta (Conrad)					×	×				×			×	×	×

POST-TEJON FAUNAL TABLE FOR WESTERN WASHINGTON—(Cont.)

	Molopophorus lincolnensis Zone	Turritella porterensis Zone	Acila gettysburgensis Zone	Arca montereyana Zone	Yoldia strigata Zone	Recent	Tejon formation of Washington	Astoria	Tunnel Point Beds	Empire	Agasoma gravidum Zone	Arca montereyana, California	San Pablo	Santa Margarita	Etchegoin
Macoma montesanoensis Weaver				X											
Macoma calcarea Gmelin				X	X	X				X					
Macoma astori Dall			X		X					X	X				
Macrocallista vespertina (Conrad)											X				
Macoma clallamensis Reagan				X											
Macoma wynootcheensis Weaver				X											
Macoma moliana Dall			X						X						
Molopophorus gabbi Dall	X														
Molopophorus lincolnensis Weaver	X														
Mytilus mathewsonii Gabb				X							X		X	X	
Mytilus sammamishensis Weaver		X													
Mytilus condoni Dall					X					X					
Mytilus snohomishensis Weaver			X												
Mytilus, n. sp			X												
Modiolus directus Dall			X				X						X		X
Modiolus inflatus Dall			X							X					
Malletia chehalisensis Arnold	X	X													
Nucula dalli Arnold				X											
Nucula washingtonensis Weaver	X														
Ostraea idriaensis Gabb	X						X								
Ostraea veatchii Gabb					X										X
Panope generosa (Gould)		X	X		X	X		X		X			X	X	X
Pitaria dalli Weaver	X										X				
Phacoides acutilineatus (Conrad)		X	X	X	X			X							
Phacoides annulatus Reeves					X	X				X			X		X
Pecten coosensis Shumard					X					X					
Pecten propatulus Conrad				X				X		X					
Pecten fucanus Arnold				X											
Pecten peckhami Gabb		X	X					X			X	X			
Pecten porterensis Weaver		X													
Pecten alockamenensis Weaver				X											
Pseudocardium gabbi Remond					X					X			X		
Pseudocardium landesi Weaver					X										
Semele montesanoesis Weaver					X										

Post-Tejon Faunal Table for Western Washington—(Cont.)

	Molopophorus lincolnensis Zone	Turritella porterensis Zone	Acila gettysburgensis Zone	Arca montereyana Zone	Yoldia strigata Zone	Recent	Tejon formation of Washington	Astoria	Tunnel Point Beds	Empire	Agasoma gravidum Zone	Arca montereyana, California	San Pablo	Santa Margarita	Etchegoin
Semele, n. sp.					×										
Solemya ventricostata Conrad			××	×				××							
Solen curtus Conrad															
Solen parallelus Gabb	×						×				×				
Solen sicarius Gould					×	×				××					
Solen conradi Dall			××												
Spisula albaria (Conrad)		×	×	×				×					××	××	××
Spisula catilliformis Conrad				×		×							×		
Spisula praecursor Dall					××					××					
Tapes staleyi Gabb					××××					×					
Tellina kincaidi Weaver															
Tellina merriami Weaver															
Tellina obruta Conrad			××	×				××							
Tellina oregonensis Conrad			×					××			×				
Tellina arctata Conrad				×											
Tellina aragonia Dall					×					×					
Tellina nuculana Dall				×				×							
Tellina congesta Conrad			×									×			
Tellina nevadensis Anderson				××											
Thracia trapezoidea Conrad		×	××	×××	×			××		×					
Thyasira bisecta (Conrad)		×	×	×××				××							
Siliqua nuttalii Conrad					×	×				×					
Venericardia subtenta Conrad				×××				×							
Venericardia chehalisensis Weaver															
Yoldia oregona Shumard			××	××××	×			××							
Yoldia impressa Conrad	×	×	×					×		×					
Yoldia submontereyensis Arnold				×××											
Yoldia strigata Dall					×					×					
Yoldia sammammishensis Weaver			×												
SCAPHAPODA															
Dentalium stramineum Gabb	×						×				×				
Dentalium conradi Dall	×	×	×	×				×		×					

POST-TEJON FAUNAL TABLE FOR WESTERN WASHINGTON—(Cont.)

	Molopophorus lincolnensis Zone	Turritella porterensis Zone	Acila gettysburgensis Zone	Arca montereyana Zone	Yoldia strigata Zone	Recent	Tejon formation of Washington	Astoria	Tunnel Point Beds	Empire	Agasoma gravidum Zone	Arca montereyana, California	San Pablo	Santa Margarita	Etchegoin
GASTEROPODA															
Ampullina oregonensis Dall				×	×					×					
Ampullina, n. sp	×														
Argobuccinum cammani Dall					×					×					
Argobuccimum coosense Dall					×					×					
Bathytoma bogachieli Reagan					×										
Bathytoma gabbiana Dall					×					×					
Brachyspingus clarki Weaver	×														
Bittium lincolnensis Weaver	×														
Buccinium bogachieli Reagan					×										
Cancellaria washingtonensis Weaver				×											
Calyptraea filosa (Gabb)	×												×		×
Calliostoma stantoni Arnold		×													
Calyptraea washingtonensis Weaver	×														
Calyptraea inornata (Gabb)					×					×			×	×	×
Chrysodomus clallamensis Weaver				×											
Calyptraea excentrica (Gabb)	×										×				
Chrysodomus maxfieldi (Reagan)					×										
Chrysodomus imperialis Dall					×					×			×		×
Chrysodomus bairdi Dall					×					×					
Chrysodomus gigantica Reagan					×										
Columbella gausapata Dall					×					×					
Crepidula princeps Conrad					×					×			×	×	×
Cymatium pacificum Dall										×					
Crepidula praerupta Conrad			×	×				×		×	×		×	×	
Cancellaria condoni Anderson				×							×				
Cancellaria wynoochensis Weaver				×											
Cancellaria dalliana Anderson				×											
Calliostoma cammani Dall					×					×					
Calliostoma delazinensis Weaver		×													
Chlorostoma arnoldi Weaver		×													
Cuma biplicata Gabb	×	×									×				
Cylichnella petrosa Conrad		×		×				×							
Drillia chehalisensis Arnold	×	×													
Epitonium condoni Dall		×													

Post-Tejon Faunal Table for Western Washington—(Cont.)

	Molopophorus lincolnensis Zone	Turritella porterensis Zone	Acila gettysburgensis Zone	Arca montereyana Zone	Yoldia strigata Zone	Recent	Tejon formation of Washington	Astoria	Tunnel Point Beds	Empire	Agasoma gravidum Zone	Arca montereyana, California	San Pablo	Santa Margarita	Etchegoin
Epitonium rugiferum Dall		×													
Epitonium washingtonensis Weaver			×												
Eudolium petrosum (Conrad)		×						×							
Eulima smithi Reagan					×										
Eulima washingtoniana Reagan					×										
Exilia dickersoni Weaver	×						×								
Fusinus montesanoensis Weaver					×										
Fusinus stanfordensis (Arnold)				×											
Fusinus corpulentus (Conrad)			×					×							
Fusinus coosensis Dall					×					×					
Drillia hecoxi (Arnold)	×	×									×				
Ficus chehalisensis Weaver				×											
Ficus wynoochensis Weaver				×											
Ficus oregonensis Conrad			×					×							
Ficus clallamensis Weaver				×											
Gyrineum sylviaensis Weaver					×										
Gyrineum mediocre corbiculatum Dall					×					×					
Hemifusus washingtoniana Weaver	×						×								
Liomesus sulcatus Dall					×					×					
Molopophorus gabbi Dall	×	×						×			×				
Miopleiona indurata Conrad			×					×							
Nassa andersoni Weaver				×											
Nassa arnoldi Anderson				×	×										
Natica oregonensis Conrad			×	×				×		×		×			
Olivella pedroana Conrad					×	×				×	×				
Polynices lewisii (Gould)	×						×								
Polynices galianoi Dall			×		×			×		×					
Polynices saxea Conrad				×								×			
Polynices clausa B & S					×										
Polynices olypidii Reagan			×												
Polynices lincolnensis Weaver	×														
Phalium aequisulcatum Dall				×	×					×					
Pisania clallamensis Reagan				×											
Ranella, n. sp					×										
Ranella marshalli Reagan					×										

POST-TEJON FAUNAL TABLE FOR WESTERN WASHINGTON—(Cont.)

	Molopophorus lincolnensis Zone	Turritella porterensis Zone	Acila gettysburgensis Zone	Arca montereyana Zone	Yoldia strigata Zone	Recent	Tejon formation of Washington	Astoria	Tunnel Point Beds	Empire	Agasoma gravidum Zone	Arca montereyana, California	San Pablo	Santa Margarita	Etchegoin
Scaphander oregonensis Dall				×	×					×					
Surcula lincolnensis Weaver	××														
Strepsidura oregonensis Dall	×××														
Strepsidura lincolnensis Weaver	××														
Sinum scopulosum (Conrad)				×	××			×		×	×				
Thais etchegoinensis Arnold															×
Turris coosensis Dall					××××					×××					
Turris coli Dall															
Turris cammani Dall					×××					×××					
Turris fresnoensis Arnold	×	×													
Turris perversa Gabb					×					×					
Turris wynoochensis Weaver				×											
Turcicula washingtoniana Dall			××												
Turritella oregonensis Conrad		×	××					×							
Turritella porterensis Weaver		×									×				
Turritella blakeleyensis Weaver			×												
Turritella newcombi Merriam			×												
CEPHALOPODA															
Aturia angustata Conrad	×	×	×	×				×	×						
ECHINODERMATA															
Scutella gabbii Rémond					×								×		
BRACHIOPODA															
Terebratula oakvillensis Weaver		×													
Terebratalia occidentalis Dall			××												
Hemithyris astoriana Dall			×					×							
CRUSTACEA															
Brachyuran remains		×	×												
PROTOZOA															
Foraminifera	×	×	×												
PISCES															
Teeth	×	×	×												